IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Ernie Davison	Examiner:	NGUYEN, Tranh N.
Serial No.	10/526,776	Group Art Unit:	2834
Filed:	March 8, 2005	Docket No.	670.001US1
Title:	HARMONIC DRIVE MOTOR		

MAIL STOP: AMENDMENT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF ERNEST DAVISON UNDER 37 C.F.R. 1.131

This Declaration of Ernie Davison is being provided in conjunction with an Amendment is filed in response to a first Non-Final Office Action on the merits mailed 18 December 2008.

CERTIFICATE UNDER 37 C.F.R. 1.8: The undersigned hereby certifies that this Transmittal Letter and the paper, as described herein, are being deposited in the United States Postal Service, as first class mail, with sufficient postage, in an envelope addressed to: Mail Stop: AMENDMENT, Commissioner for Patents, PO Box 1450, Alexandria, VA 22313-1450 on 16 May 2008.

Mark A. Litman
Name

Signature

DECLARATION

I, Ernest Davison, who is usually referred to as ":Ernie Davison," do hereby state and declare as follows:

1. I am the Ernie Davison identified as the sole inventor on U.S. Patent Application Serial No. 10/526,776, filed March 8, 2008, hereinafter referred to herein as the "Application.".

2. I have read and reviewed the Application, the Office Action mailed by the U.S. Patent and Trademark Office on 18 December 2007, and the references cited therein.

3. I have also read and reviewed Provisional Applications filed in my name in the U.S. Patent and Trademark Office on various dates, including at least:

a) U.S. Provisional Application No. 60/316,294, filed 4 September 2001;

b) U.S. Provisional Application No. 60/322,471, filed 17 September 2001;

c) U.S. Provisional Application No. 60/347,253, filed 14 January 2002;

d) U.S. Provisional Application No. 60/355,832, filed 13 February 2002;

e) U.S. Provisional Application No. 60/305,937, filed 17 July 2001;

f) U.S. Provisional Application No. 60/316,293, filed 4 September 2001; and

g) U.S. Provisional Application No. 60/316,295, filed 4 September 2001.

4. The subject matter of the seven provisional applications listed directly above comprises the subject matter disclosed and claimed in the Application.

5. After review of the subject matter disclosed in the seven provisional applications listed directly above, I believe that there is substantive disclosure of the concepts and limitations recited in all claims presently submitted by Amendment in the Application in May of 2008 with an accompanying Amendment and Response.

6. The disclosure of the subject matter of the seven provisional applications listed directly above shows that I was in possession of the subject matter and recitations and limitations of the claims submitted in the Amendment filed in May of 2008 as of dates including at least **4 September 2001** and **17 July 2001** and that additional information, not necessary for support of the claims in the Amendment filed in May of 2008 in the Application, was also available to me.

7. As this clear and convincing physical evidence of knowledge of the subject matter of the claims of the Application (as submitted in May of 2008) was clearly in my possession as of 17 July 2001 (at the latest, as these provisional applications and their subject matter were also in my possession before filing in the U.S. Patent and Trademark Office), I have established constructive conception and reduction to practice of the claimed subject matter of the May 2008 Amendment in the Application at a date no later than September 4, 2001.

8. The Office Action mailed on 18 December 2007 included the following rejection:

i) "Claims 1-2, 5-6, 16 and 20 have been rejected under 35 U.S.C. 103(a) as unpatentable over US Patent No. 4,227,092 (Campagnuolo et al.) in view of U.S. Patent No. 6,566,777 (Abu Akeel).

On review of this rejection, it is to be noted that the reference date available for U.S. Patent No. 6,566,777 (Abu Akeel) is 5 October 2001, a date later than that of the four Provisional applications identified above and filed on 4 September 2001, 17 September 2001, and 17 July 2001.

9. Upon advice of counsel, Mark A. Litman, I believe that the fact that there is irrefutable physical and dated evidence of the possession of the full scope of the invention recited in the claims submitted in the Amendment dated May 2008 in the Application, that the Akeel reference has been removed as prior art against these claims, as the available reference date of Akeel is later than the evidenced possession of the invention as claimed by me.

10) Claims 1, 2, 5, 6, 9-11, 13, 16 and 20 have been rejected;

a. Claims 1-2, 5-6, 16 and 20 have been rejected under 35 U.S.C. 103(a) as unpatentable over US Patent No. 4,227,092 (Campagnuolo et al.) in view of U.S. Patent No. 6,566,777 (Abu Akeel).

Applicant, by providing this Declaration under 37 C.F.R. 1.131 evidencing conceptual, constructive and/or actual reduction to practice of the subject matter of these claims, has overcome this rejection by removal of the Akeel reference.

11) Applicant submits herewith the physical evidence supporting this declaration, including at least the following provisional U.S. Patent Applications:

1) EDM Provisional Patent Application 60/316,294
   Filing Date Sept 4,2001**(Full text)**;
2) EDM Provisiona lPatent Application 60/322,471
   Filing Date Sept17,2001 **(Filing cover sheet, Abstract and Figures)**;
3) 3)EDM Provisional Patent Application 60/347,253
   Filing Date Jan14,2002 **(Filing cover sheet)**;
4) 4)EDM Provisiona lPatent Application 60/355,832
   Filing Date Feb13,2002 **(Filing cover sheet)**;
5) 5)EDM Provisional Patent-Application 60/305,837
   Filing Date July17,2001 **(Filing cover sheet)**;
6) 6)EDM Provisional Patent-Application 60/316,293
   Filing Date Sept4,2001 **(Filing cover sheet)**; and
7) EDM Provisional Patent-Application 60/316,295
   Filing Date Sept4,2001 **(Filing cover sheet).**

These documents as filed, and as already present in the US Patent and Trademark Office provide clear and complete evidence of the conception of the subject matter claimed in the present application as early as July 17, 2001; September 4, 2001 and September 14, 2001, each of these dates being earlier than the reference date available for U.S. Patent No. 6,566,777 (Abu Akeel), which has an available reference date of 5 October 2001. As that reference is an essential element of this rejection and is no longer available for the present rejection, this rejection must be withdrawn.

Applicant has provided sufficient pages from these documents to evidence that the subject matter of the claims is evidenced in the documents as filed.

FURTHER DECLARANT SAYETH NOT

Signed this 16th day of May 2008.

Ernest Davison

ERNIES copy as filed

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PTO/SB/16 (2-98)
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)

Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
ERNEST	DAVISON	NASSAGEWAYA ONTARIO, CANADA

☐ Additional inventors are being named on the ___ separately numbered sheets attached hereto

TITLE OF THE INVENTION (280 characters max)

DOUBLE ENDED DRIVE FOR A FLEXISPLINE MOTOR

CORRESPONDENCE ADDRESS

Direct all correspondence to:

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26976
PATENT TRADEMARK OFFICE

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ENCLOSED APPLICATION PARTS (check all that apply)

✓ Specification Number of Pages	21	☐ Small Entity Statement	
☐ Drawing(s) Number of Sheets	7	✓ Other (specify)	Abstract; Claims 6 pgs

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)

		FILING FEE AMOUNT ($)
✓ A check or money order is enclosed to cover the filing fees		
☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number:	15-0445	75.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☐ No

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE E.H. Oldham by Mgt.

TYPED or PRINTED NAME E.H. Oldham

TELEPHONE 627 0509 Area Code 905

Date 30108101

REGISTRATION NO. (if appropriate) 25314

Docket Number: EH001153

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C., 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C., 20231.

APPLICATION # 60/316,294
4/SEPT/01

EHO 01153

DOUBLE ENDED DRIVE FOR A FLEXISPLINE MOTOR

FIELD OF INVENTION

This invention relates to a high torque motor which as part of its construction contains a magnetically permeable cup which is elastically distorted by the influence of a magnetic field. This cup has the classical shape of an open ended "tin can" in which a cylinder and an end disc are integrally connected. The open end of the disc or sleeve is "wrapped" with a band carrying external gear teeth which is also capable of undergoing elastic deformation as the cylinder of the cup is deformed. When the magnetically permeable cup is exposed to a rotating magnetic field, an elastic distortion is produced which manifests itself as a "wave" phenomena progressing around the open end of the cup. That is the open end of the can assumes the shape of an ellipse which shape continues to rotate about the longitudinal axis of the cup.

The open end of the cup on which the band gear is located is usually surrounded by a ring gear (which does not undergo any significant distortion) which is contacted by the band gear at two opposing points at the ends of the major axis of the elliptical shape.

The band gear and the ring gear have teeth which mesh; both sets of teeth have the same pitch but differ in number. As the elliptical shape of the end of the cup sweeps about the central axis of the cup, the teeth of the band gear are progressively engage different teeth of the ring gear; because of the differing number of teeth on the two gears, relative rotation of the two gears occurs. This gearing phenomenon is well known and is usually referred to as strain wave gearing.

BACKGROUND OF THE INVENTION

The principles of strain wave gearing or flexispline drives are well known and are discussed in U.S. Patent 2,906,143 (September 29, 1959) and 2,931,248 (April 15, 1960) issued to Musser. There the underlying principles involving the continuous oscillatory contact of a flexible spline (flexispline) with a ring gear to produce a rotational output from the ring gear are discussed in some detail. A torque is produced in the ring gear by the continuous elastic deformation of the flexible spline's gear tooth ring by a device called a strain inducer to cause the teeth on the flexispline to be driven into sequential engagement with the teeth of the ring gear. Because the flexispline and the ring gear have a different number of teeth, the ring gear is forced to rotate a distance equal to the small tooth

difference (generally two teeth for elliptical distortion) between the flexispline and the ring gear for one revolution of the strain inducer. Providing that the number of teeth on the flexispline and ring gear is large and the tooth differential is small between the flexispline and the ring gear (as it usually is), a tremendous gear reduction ratio can be realized between the rotation of the strain inducer and the ring gear. The output torque is developed from the continuous sequential meshing of the teeth of the flexispline with the ring gear and is proportional to the inverse of the gear ratio. This torque is generated by the strain inducer which is constantly distorting the flexispline to engage the ring gear in a sequential manner.

Since 1959 a number of electromagnetically driven strain wave gearing units have been produced to provide rotational motion for specific purposes. The size and shape of the unit may change, but the continuous sequential distortion of a flexible cylinder is always present to produce rotational motion at modified speeds.

SUMMARY OF THE INVENTION

This invention describes an electromagnetically driven flexispline arrangement of the type wherein both the flexispline and the "stator" core of the motor remain rotationally stationary during operation of the unit.

Both the flexispline and the stator core comprise an electromagnetic system for which a rotating magnetic field is generally produced by a set of inverted stator windings placed inside the flexispline which in turn produces a magnetic flux to distort the flexispline. In this instance the stator windings are carried by the central "core" or the part of a conventional electric motor which is usually occupied by the rotor.

The "stator core" comprises a body of laminated magnetic material or its equivalent to enhance the concentration of the magnetic field produced by a set of windings carried by the "stator core".

These stator core windings are made to produce a rotating magnetic flux which passes from the core, then into the flexispline and returns to the core. This magnetic flux is produced by passing a modulated current through the core windings. The resultant magnetic flux produces a rotating radially directed force.

The stator core itself is generally mounted on a sturdy stationary central post which may be hollow and comprised of an electrically resistive (ohmic) material which serves to provide a rigid mounting means for the ring gear hub and any external load carried by the hub at the end of the post. The hub is mounted on the post so that the ring gear provided in the hub enjoys a close concentric relationship with the stator core and the flexispline. A set of bearings assures that the coaxial

relationship of the "core" and the ring gear is maintained during rotation of the hub.

The hub may be connected to an output shaft or a screw actuator to produce rotational power. It may also be mounted within a wheel of a vehicle to provide power to drive the wheel. When the device of this invention is mounted within a wheel, the shaft must also support the cantilevered load of the extended shaft and bearings.

When compared to the prior art two essential features become evident; 1) the stator core is surrounded by the distorting flexispline, and 2) the flexispline itself provides a return path for the magnetic flux. This improves the applicability of this device to more diverse applications and allows the flexispline diameter to be increased drastically over the prior art motors. These features make it possible to increase the output torque, power and efficiency of the device over the prior art models.

PRIOR ART

U.S. Patent 2,906,143 Musser September 29, 1959

This patent describes in detail the principles of strain wave gearing using a mechanical strain inducer to distort the flexispline. At Figures 54 and 55 Musser briefly describes a method of operation of a flexispline

device driven by a polyphase electrical input and a series of electrical solenoids.

U.S. Patent 3,169,201 Spring et al February 9, 1965

This patent describes a flexispline motor having an external stator (which is stationary) comprising a number of circumferentially distributed salient poles (axially aligned solenoid pole pairs) having an adjacent ring gear also mounted in the stator adjacent the poles.

A flexispline rotor is attached to a shaft and is mounted for rotation within the stator and is provided with external gear teeth on the exterior surface thereof to mesh with a ring gear encircling the flexispline. The flexispline rotor is provided with a radial series of magnetically permeable axially aligned laminations mounted under its surface and allowed to pivot about one end (acting as a lever). These laminations are fastened to a rotor fulcrum ring and encouraged to pivot when subjected to a radial magnetic force. A substantial mechanical advantage results. Upon actuation by a sequentially pulsed rotating magnetic field, the laminations pivot outwardly to cause the flexispline to distort and contact the surrounding ring gear. This causes rotation of the flexispline rotor and its attached shaft (in a direction opposite the direction of the rotating magnetic field). The rotor thus moves in accordance with the tooth

differential existing between the ring gear and the flexispline gear giving rise to substantially reduced rotational motion at the output.

U.S. Patent 3,496,395 Newell February 17, 1970

In one described embodiment of this technology, a stator is supplied with a set of windings to produce a rotating magnetic field. The stator comprises a series of stacked laminations which not only serve to provide a mounting system for the windings but also serve to provide a surface for attaching a stationary co-axial ring gear in the air gap between the stator and the flexispline rotor. The stationary ring gear has internally extending teeth which are engaged by the flexispline rotor externally extending teeth as it is distorted by a rotating magnetic field.

The flexispline rotor in this instance is a thin flexible magnetically permeable hollow cylinder having ends closed by membranes which support and allow deflection of the cylinder but limits the magnetic flux flow through it.

A shaft is made to pass through the central axis thereof. The closed ends of the flexispline cylinder are fastened to the shaft so that any rotation of the flexispline is transferred to the central shaft.

The rotating flexispline is provided with a gear which is mounted or formed in the surface thereof to contact the internally extending teeth of the stationary ring gear.

The magnetic flux produced by the stator windings passes into and returns from the "hollow" flexispline tube to produce a magnetic attraction force. Thus the circular shape of the cylindrical flexispline tube is distorted outwardly to force the teeth of the flexispline into engagement with the teeth of the stationary ring gear. The flexispline rotor thus rotates according to the tooth differential of the two sets of meshing gears, but in the opposite direction to the rotating magnetic field.

The major focus of this patent is to produce a biased coiled magnetically permeable flat strip within the flexispline rotor to enhance the magnetic attraction between the flexispline and the stator and to reduce edge effect discontinuities which effect the position control accuracy in a servomotor positioning application.

U.S. Patent 3,169,202 Proctor et al February 9, 1965

This patent describes a flexispline motor having a fixed external stator in which conventional three phase induction windings and a stationary ring gear are mounted. A flexispline having pockets of powdered iron arranged beneath its surface, is influenced by a rotating

magnetic field to distort under the attractive force of that field. This causes engagement of the flexispline gear with the stationary ring gear to produce motion in accordance with the tooth differential of the flexispline gear and the ring gear.

Various rotor constructions are shown in this patent, all designed to enhance the magnetic force attraction produced in the rotor by the magnetic field.

U.S. Patent 3,609,423 Spring September 28, 1971

This patent proposes the use of a tapered coil of flat flexible magnetic material beneath the flexispline to enhance elasticity and magnetic force attraction of the flexispline. The magnetic material is strategically slotted axially to decrease eddy current circulation.

U.S. Patent 5,691,584 November 25, 1997

This patent is an excellent example of the "state-of-the-art" electrically driven vehicle in which a drive motor is located within the wheel and is connected through a double reduction gear transmission to produce a high driving torque.

U.S. Patent 5,600,191 February 4, 1997

This relatively recent patent describes a driving assembly for a wheel in which low torque requirements are produced by an "inside out" motor where the stator carries permanent magnets.

U.S. Patent 4,389,586 June 21, 1983

This patent describes a driving arrangement for the wheel of a very large "off-the-road" vehicle. A DC motor drives the wheel through a double reduction gear train.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross sectional view of an energy transfer device (motor) of this invention.

Figure 2 is an exploded perspective view of the device of Figure 1.

Figures 3A, 3B and 3C show the distortion of the flexispline of Figures 1 and 2 as the magnetic field rotates.

Figure 4 is a cross sectional view of an alternative embodiment of this invention.

Figure 5 is yet another embodiment of this invention shown in cross section.

Figure 6 is a sectional view of a flexispline and core shown at 6-6 in Figure 1.

Figure 7 is a sectional view of an alternate construction of the device of Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figures 1 and 2 in which wheel motor 10 is shown as a cross section Figure 1 and as an exploded view in Figure 2. The motor 10 is mounted on base plate 12 which in this illustration is provided with four threaded holes 14. The number of threaded holes depends on the application; there may be more or less holes 14 depending on the required output. A sturdy post 16 (which is preferably hollow, non-magnetic and of a high ohmic resistance) is mounted on base plate 12 so as to project orthogonally therefrom.

Post 16 is provided with keyway 18 and wheel bearing mounting segment 20. Post 16 terminates in a threaded end 22.

A somewhat cupshaped flexible sleeve 24 (flexispline) is mounted on base plate 12 between a pair of spacers 26 by means of screws 28 so that it may not rotate. Sleeve 24 has a closed end 30 (which may be of somewhat heavier construction than the cylindrical upstanding portion 32) which is integrally attached to end 30.

Sleeve 24 has an open end 34 remote from end 30. The end 30 of flexispline 24 has a locating hole 36 provided therein to guide the flexispline along post 16 during installation, and the opening 36 serves to center and locate the flexispline 24 on base 12 so that the holes 38 and 40 in the spacers 26 and end 30 of flexispline 24 may be easily aligned with threaded holes 14 of base plate 12 for ease of assembly and to maintain gearing tolerances.

The cylindrical upstanding portion 32 of flexispline 24 is provided with an external toothed gear 42 at or near the end 34 of flexispline 24. The flexispline 24 (in this instance) is composed of a highly permeable magnetic material having a high magnetic saturation level, as well as exhibiting a high resistance to eddy current circulation.

A suitable material for flexispline 24 for this application would be iron or iron alloys including steel silicon, nickel and/or cobalt. The cylindrical shell 32 is purposely made to be what is generally referred to as a "thin walled" member so that its usual shape (at rest, i.e. a cylinder) may be readily distorted to take on the general shape of an ellipse (when compelled by the magnetic force to change from its normal shape).

The deflection of the wall 32 of the flexispline 24 may be determined by the following equation:

$$P = \frac{K \Delta L t^3 E}{r^3} \text{ ---------- (1)}$$

where K = a constant

Δ = diametrical deflection of cup (approximately twice the gear tooth height)

P = radial distorting force

L = axial length of the cup

t = wall thickness

E = flexural modulus (or composite flexural modulus)

r = radius of sleeve

One of the characteristics which must be determined with respect to the flexispline 24 before degree of deflection force is finally determined, is the amount of torsional twisting (shear stiffness) the flexispline 24 must withstand during operation. The spline gear 42 mounted or formed on the outer surface of the sleeve will have a significant influence on the sleeve stiffness. Equation (1) above will also apply to the presence of spline gear 42 on flexispline 24 as well. In addition, it may be found that it is necessary to coat spline gear 42 with a hard coating to improve its wear characteristics.

The flexispline 24 is mounted on base plate 12 by sliding it along post 16 until holes 38 and 40 line up with threaded holes 14. Countersunk screws 28 are threaded through holes 38 and 40 into the threaded holes 14 to hold the flexispline 24 firmly between spacers 26 against base 12.

Next a magnetic core 44 is slid into place on post 16 and is rigidly mounted and located on post 16 in its "home" position and held in this location (in this instance) by means of key 46 in keyway 18. A corresponding keyway (not shown) is formed in core 42 to compliment the keyway 18 formed in post 16.

Core 44 is supplied with a winding 48 which is wound in core slots 50 formed in the surface of core 44 in such a manner as to provide the rotating magnetic field when energized. This field ultimately causes the flexure of the wall 32 of flexispline 24.

A conventional three phase two pole winding may be used to provide the necessary deflection of the sleeve 32 of flexispline 24.

Next a hub 52 (on which a wheel may be mounted) is rotatably journalled on post 16 by means of thrust bearings 54, 56 which are mounted on bearing segment 20 of post 16. In this instance, hub 52 is a robust casting having a similar shape to a truck or transport hub and brake drum assembly.

Hub 52 is provided with a pair of bearing recesses to receive a pair of thrust bearings 54 and 56 therein to assure that hub 52 is firmly locked into position and rotates concentrically with the axis of post 16.

Cylindrical shell 60 of hub 52 is provided with a cantilevered shell portion 62 which is provided with an internal spline gear 64. Gear 64 is made to have teeth which mesh with the teeth of spline gear 42 of flexispline 24 but the teeth comprising gear 64 are intentionally made to be different in number than the teeth in spline gear 42.

Hub 52 may be provided with a series of studs such as 66 for mounting a wheel rim thereon.

Referring now to Figures 3A, 3B and 3C, motor 10 is represented in cross section as taken along the axis of post 16, showing the distortion of flexispline 24 as the magnetic flux rotates about the axis of motor 10. Note that core 44 and flexispline 24 are rotationally stationary, but gear 64 is forced to rotate in the same direction as the rotating magnetic field.

The magnetic material comprising flexispline 24 is attracted to core 44 at the point where the magnetic flux emanating from core 44 is greatest; at this point the interior surface of flexispline 24 is usually designed to be in contact with the exterior surface of core 44.

The rotating elliptical shape of flexispline 24 may in time produce wear on the surface of core 44 even though flexispline 28 and core 44

have no rotational motion (both are stationary). Flexispline 28 oscillates about the axis of motor 10 with a very small amplitude.

Because of this it may be necessary to provide the contacting surfaces of flexispline 24 and core 44 with a lubrication which may be in the form of a solid lubricant incorporated into the surface of core 44. Core 44 may be fabricated from iron laminations stacked to the desired length, or core 44 may be a composite, having finely divided particles of a magnetic material encapsulated in a polymeric substance. The latter composite provides a material having good magnetic permeability characteristics, while providing excellent resistance to the flow of three dimensional eddy currents. The composite core just described also provides a surface in which it is quite possible to incorporate a solid lubricant to reduce frictional losses (which leads to less production of heat in the core) and also to help dampen any vibrations due to system resonances.

Figure 4 shows the modification of the device of Figure 1 wherein the ring gear (62 of Figure 1) is now gear 162 located on the interior of flexispline 124. The core 144 is provided with winding 148 to provide the magnetic attraction of flexispline 124 toward core 144. The basic difference in operation of the device of Figures 1 and 4 is that the flexispline 24 of Figure 1 contacts the ring gear 62 at an angle of 90°

from the point of maximum flux force produced by core 44 where as the point of contact of flexispline 124 with ring gear 162 is coincident with the maximum flux force produced by winding 148 on core 144 in Figure 4.

Figure 5 shows an enhancement for the device of Figures 1 and 4. Most of the components of Figure 5 are identical to the components shown in Figure 1.

A flexispline 244 is mounted on base 212. Core 244 carrying winding 248 is mounted on post 216 and locked in place with key 246.

The major difference is the presence of a winding a multilayer wire 280 wound on the surface of flexispline 224. Winding 280 in this instance is shown having a circular cross section and is wound as a helix around flexispline 224. The winding 280 comprises a magnetic material to enhance the magnetic attraction of the flexispline 224 to core 244 and to minimize the generation of eddy currents.

The winding 280 may be wound and bound to the surface of the flexispline as in a filament winding process or as a preformed coil which is bound or shrunk to the flexispline surface. In either case the objective is to minimize the thickness of the flexispline-coil combination (to keep the distortions stiffness to a reasonable figure, whilst maximizing the area for the flow of magnetic flux.

To obtain a better fill factor and reduce the number of radial aircaps in the wire layers, the wire comprising the winding 280 may have a square or rectangular cross section with axial thickness of about 0.014" to 0.025". Suitable compositions for the wire comprising winding 280 are Carpenter Silicon Coretron B.

The turns of winding 280 should be insulated (preferably on the axial facing only) from each other to reduce eddy current flow in winding 280, usually an oxide or phosphate coating formed on the turns comprising winding 280 is sufficient for this purposes. Note that there is no electrical continuity between the wire layers because the wire ends at both ends of the flexispline 224.

It will be found that by the judicious selection of dimensions and the polymeric material binding the wire winding 280 of motor 210, the distortion stiffness of the combined flexispline 224 and winding 280 may be reduced by a factor of 3 or more in comparison with an equivalent solid metal flexispline without adding significantly to the stiffness exhibited by the flexispline 224 – wire 280 composite.

Figure 6 is a representation of the Section 6-6 shown in Figure 1. The flexispline 24 is shown surrounding the core 44. Three windings 48a, 48b and 48 c comprise winding 48. This is a three phase "sinusoidally distributed" winding which is a traditional winding. The

three phase windings 48a, 48b and 48 c are distributed about the core 44 in a well known manner. This winding will serve to deflect the flexispline in the manner described previously; it matters not whether additional layers such as 224 has been applied to the surface of the flexispline 24.

Referring to Figure 7, an alternative form of the invention of Figures 1, 4 and 5. Here the flexispline motor 410 is shown mounted on base 412. A tubular member (preferably magnetic) 416 is firmly mounted on base 412. A magnetic core 444 is securely mounted on member 416 by means of key 446 or some other suitable method of bonding. Windings 448 are wound on core 444 as shown in Figure 6.

The end 430 of flexispline 424 is firmly attached to baseplate 412 by means of spacers or flanges 426 and screws 428 as to be coaxial with quill 416 in its rest position. At the remote end 434 of flexispline 424 is a band gear 442 which encircles the open end of flexispline 424 on the exterior surface thereof.

A driven element 452 is mounted in bearings 454 and 456 inside quill 416. Driven element 452 comprises a disc 470 attached to shaft 472 which extends through base 412 to form shaft projection 474, and disc 470 may carry wheel studs such as 476 or a shaft extension such as 478 (in the absence of studs 476).

This construction allows the flexispline motor 410 to be adaptable to drive a load from either or both ends simultaneously.

A winding similar to winding 280 may be incorporated into the structure of flexispline 424 to improve its magnetic characteristics. Of course the motor structure may take the form of the flexispline motor in Figure 4 wherein the flexispline 424 would surround the ring gear.

In summary, the flexispline motor of this invention places the electro-magnetic core inside the flexispline. This construction has definite advantages over prior art devices in that the motor may be much smaller and less complicated than previous devices.

The torque and power produced by a flexispline motor depends to a large extent on the (diameter^2) of the flexispline. In prior art devices the flexispline is surrounded by an electro-magnetic core structure; thus the diameter of the flexispline is much less than the external diameter of the motor structure. The applicant's structure places the flexispline near the outer extremities of the motor increasing the torque versus motor size ratio significantly when compared to prior art motors.

The structure of the flexispline motor of this application is ideally suited for applications such as traction motors because of the compactness and the requisite high torque capability, and the ability to free wheel when the winding such as 48 is unexcited.

The addition of the composite flexispline having a filament winding reduces the radial distortion thickness whilst maximizing the return path magnetic flux flow area. This improves the power output by increasing the torque and improving the efficiency of the device.

What is claimed:

1. A flexispline motor having a base, a hollow post affixed to said base, a cylindraceous magnetic core and a flexispline mounted on said base and said hollow post so as to enjoy a coaxial working relationship with said hollow post,

said core being provided with a set of suitable windings to produce a rotating magnetic field,

a flexispline comprising a disc portion and cylindrical portion integrally joined together to form the general shape of an open ended "tin can" mounted on said support means in such a manner that it encompasses said magnetic core and is in a coaxial relationship with said core, said cylindrically shaped portion of said flexispline comprising an elastically deformable magnetic material and being in a closely spaced relationship with said core but not touching said core in an unexcited magnetic state,

said flexispline having toothed external gear means formed thereon in the form of an elastically deformable band encircling the exterior surface of said cylinder near the open end of said flexispline,

shaft means mounted within said post means on suitable bearings for rotation within said post and passing through said base, said shaft means being connected to a disc shaped hub at an end opposite said base,

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ring gear means carried by said hub in a working relationship with said flexispline,

said ring gear means and flexispline gear means having gear teeth that will mesh, but differ in number,

said open end of said flexispline and said gear means being distorted in the presence of a magnetic field in said core to form a general elliptical shape such that said gear means on said flexispline exhibits toothed engagement with said ring gear on said hub at the two opposite points on the major axis of the elliptical shape so formed.

2. A flexispline motor having a cylindraceous magnetic core, a flexispline and rotatable hub means mounted on a suitable shaft means at a point intermediate its ends, said shaft means passing within said magnetic core and being supported on suitable bearing means,

said shaft means being accessible at both ends of said motor,

said core being provided with a set of suitable windings to produce a rotating magnetic field,

a flexispline comprising a disc portion and cylindrical portion integrally joined together to form the general shape of an open ended "tin can" mounted on support means in such a manner that it encompasses said magnetic core and is in a coaxial relationship with said core, said cylindrically shaped portion of said flexispline comprising an elastically

deformable magnetic material and being in a closely spaced relationship with said core but not touching said core in an unexcited magnetic state,

said flexispline having an elastically deformable toothed internal gear means formed thereon on the interior surface of said cylinder in the form of a band, near the open end of said flexispline,

hub means carrying a ring gear means mounted within said flexispline and extending coaxially with said flexispline, said ring gear means being encircled by said elastically deformable toothed internal ring gear means of said flexispline,

said gear means and said internal ring gear having teeth which will mesh but differ in number and being in closely spaced relationship, but not touching in an unenergized magnetic state,

said internal gear means being distorted upon the presence of a magnetic field in said core to assume an elliptical shape and contact said ring gear at the minor axis of the elliptical shape so formed.

3. A flexispline motor as claimed in claim 1 wherein said flexispline has an exterior surface wound with a helix of a magnetic wire material.

4. A flexispline motor as claimed in claim 2 wherein said flexispline has an exterior surface wound with a helix of a magnetic wire material.

5. A flexispline motor comprising a base, having hollow post means mounted on said base to support a cylindraceous magnetic core thereon and a rotatable shaft mounted within said hollow post means and protruding from at least one end of said hollow post means,

said base and hollow post also supporting a magnetic flexispline having the shape of an open ended tin can which extends coaxially with said post and magnetic core so as to closely surround said magnetic core but not touch it at a rest condition,

said flexispline having external gear means formed therein near the open end thereof extending completely around said flexispline,

said shaft having complimentary ring gear means mounted thereon in a working relationship with said flexispline gear means, said ring gear means surrounding said external gear means on said flexispline in closely spaced relationship,

said ring gear means and said flexispline external gear means having teeth which will mesh, but differ in number,

winding means on said core to establish a rotating magnetic field in said core,

said flexispline undergoing a cyclic elastic deformation in the presence of a rotating magnetic field in said core to distort said open end of said flexispline from a circle to an ellipse,

said external gear means also being distorted to form an ellipse in the presence of a magnetic field in said core, wherein the external gear means engages said ring gear at the extremities of said ellipse major axis to cause said ring gear and shaft to rotate.

6. A flexispline motor comprising;

a cylindraceous magnetic core having an electrical winding system incorporated in said core,

a flexispline comprising a disc portion and a cylindrical portion integrally joined together to form the general shape of an open "tin can" first gear means formed on said cylindrical portion near the open end thereof, said cylindrical portion being formed of an elastically deformable magnetic material , said flexispline being supported in said motor so as to enjoy a coaxial overlying relationship with said core,

hub means mounted on a shaft supported in said motor for rotation about an axis which is coaxial with and passes through said core and flexispline, ring gear means provided on said hub encircling said first gear means, said ring gear means and first gear means having teeth which mesh but differ in number, said flexispline being mounted in said motor so that at rest said first gear means does not touch any part of said ring gear, but upon distortion of said flexispline in the presence of a suitable magnetic field, said first gear means assumes an elliptical shape wherein

said first gear means engages said ring gear at the opposing ends of the elliptical shape so formed,

said shaft having two ends which protrude from both ends of said motor.

ABSTRACT

A flexispline motor having a flexispline member of the shape of an open tin can, such that under rest conditions the space between the flexispline and an inner contained core is constant under rest conditions. The flexispline has a flexible ring gear incorporated in its outer surface near the open end which when magnetically excited ceases to have a circular shape and forms an elliptical shape. Under these conditions the points of major axis of the ellipse so formed contact a surrounding ring gear which is mounted on a rotating hub mounted on a shaft which passes through the motor and protrudes from both ends of the motor. The points of the flexible ring gear which correspond to the minor axis contact the surface of the core. As the magnetic force rotates the elliptical shape rotates, but the flexispline itself does not rotate. Because the number of teeth on the ring gear and the flexible gear are different, the hub is forced to rotate.

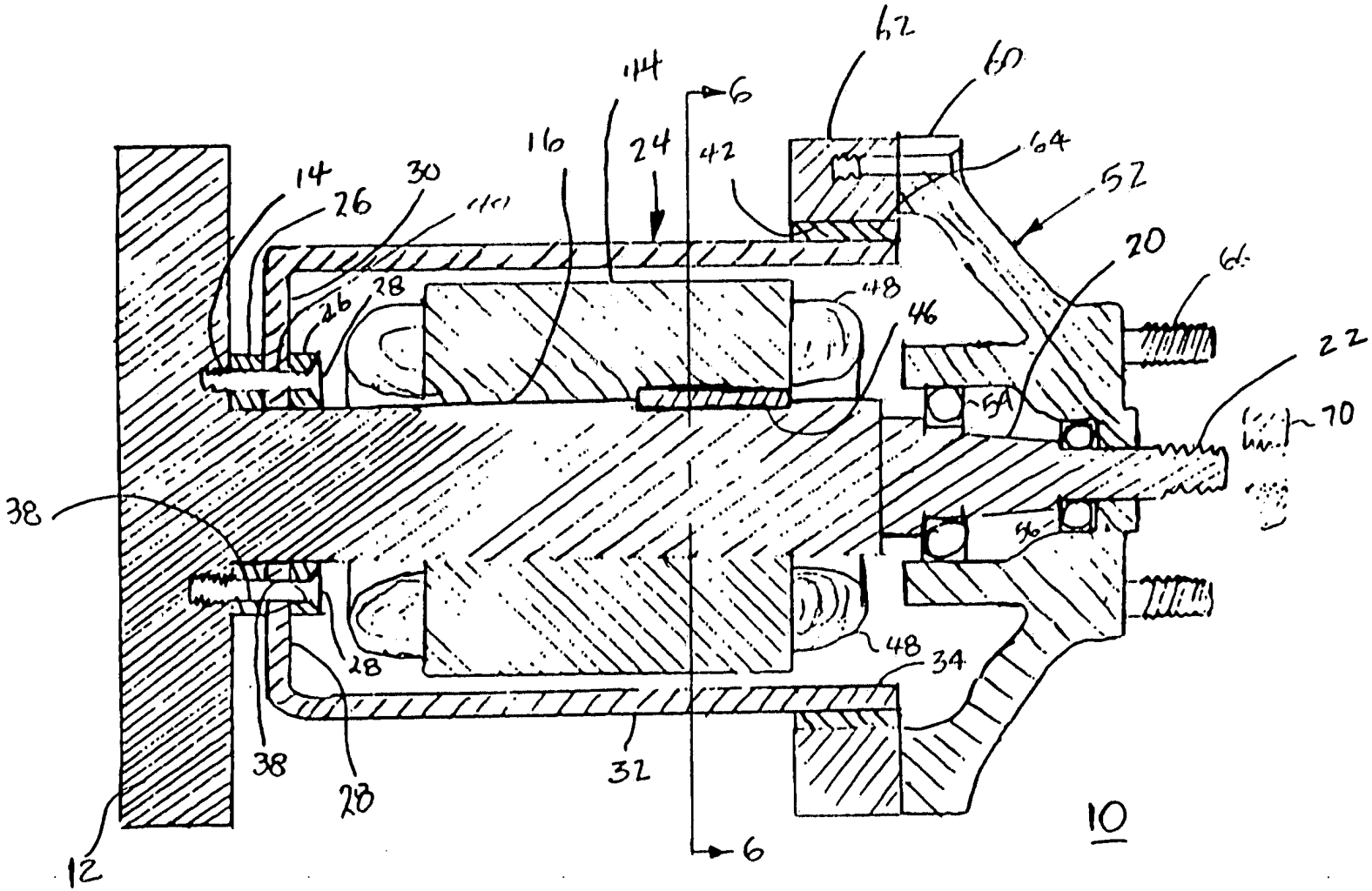
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FIGURE 1

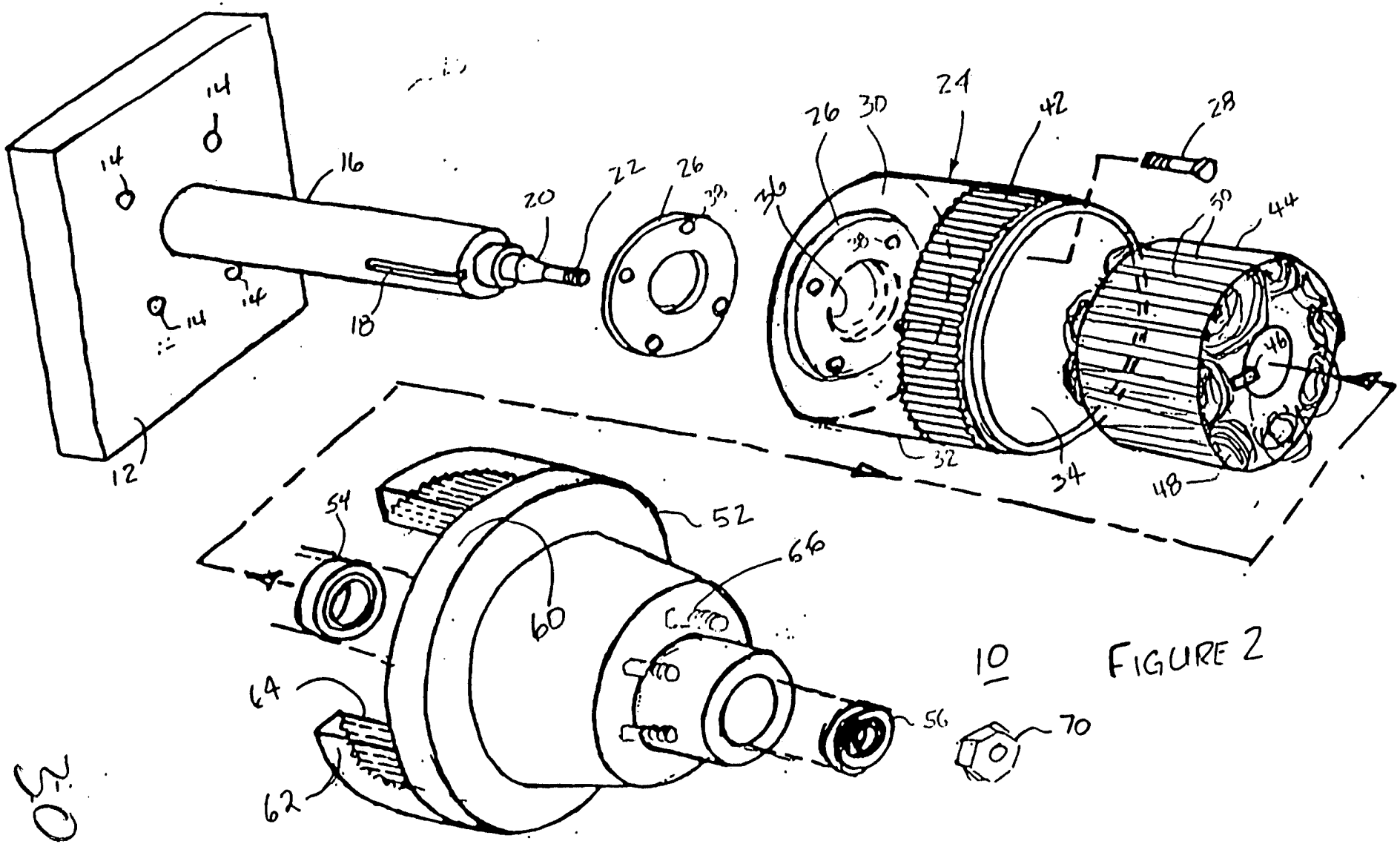
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FIGURE 2

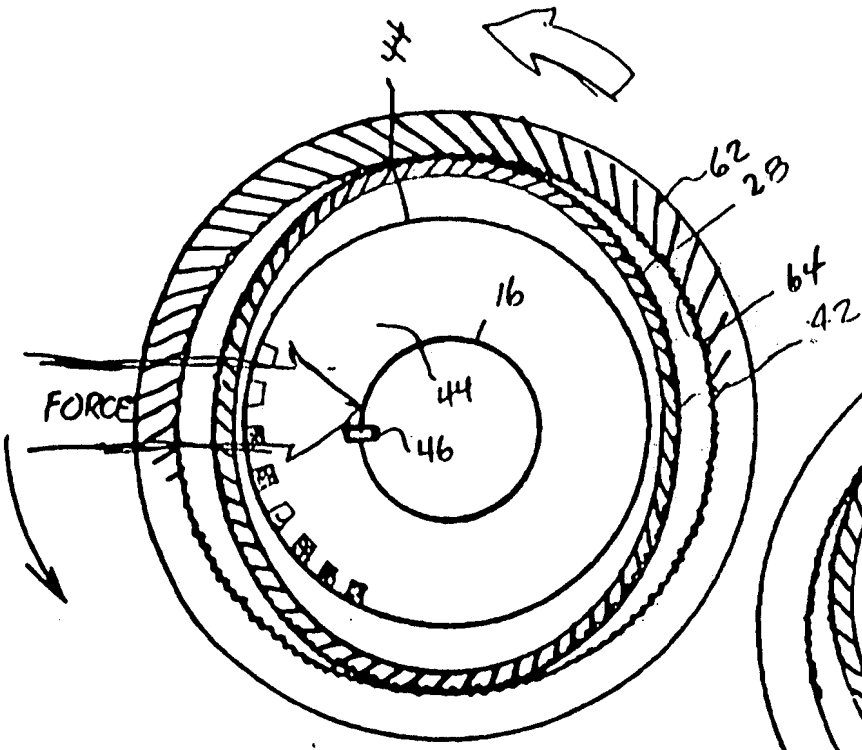

FIG 3A

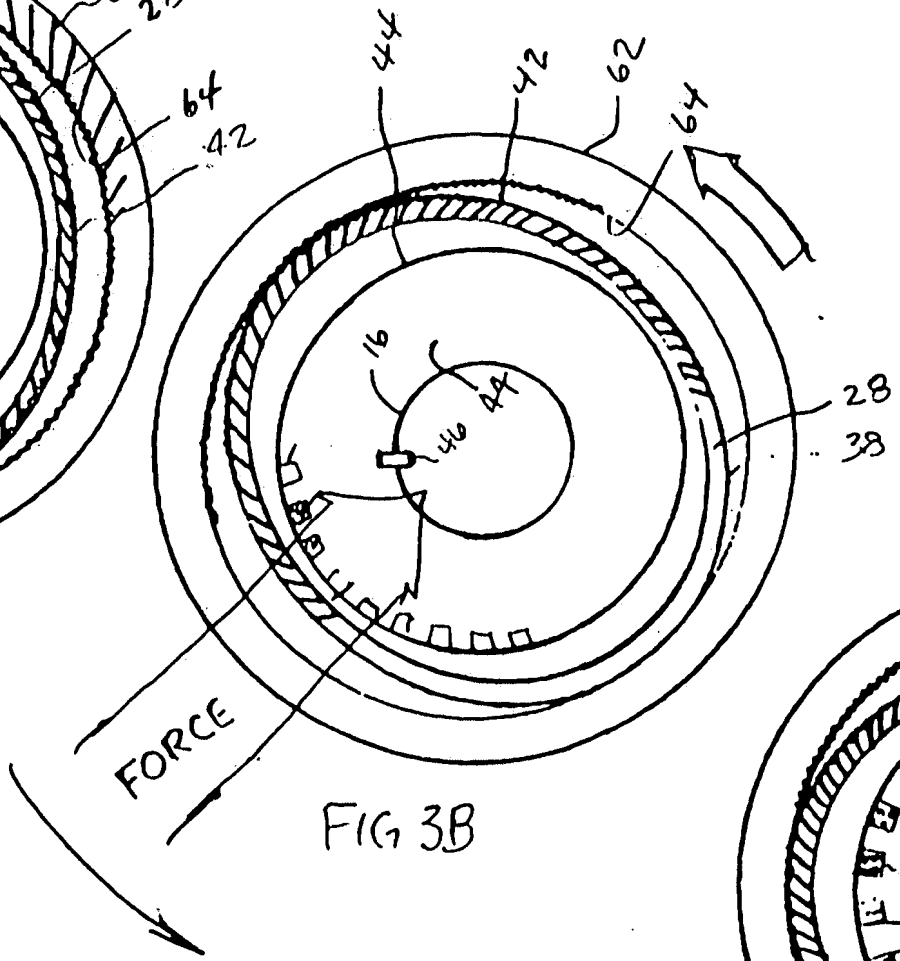

FIG 3B

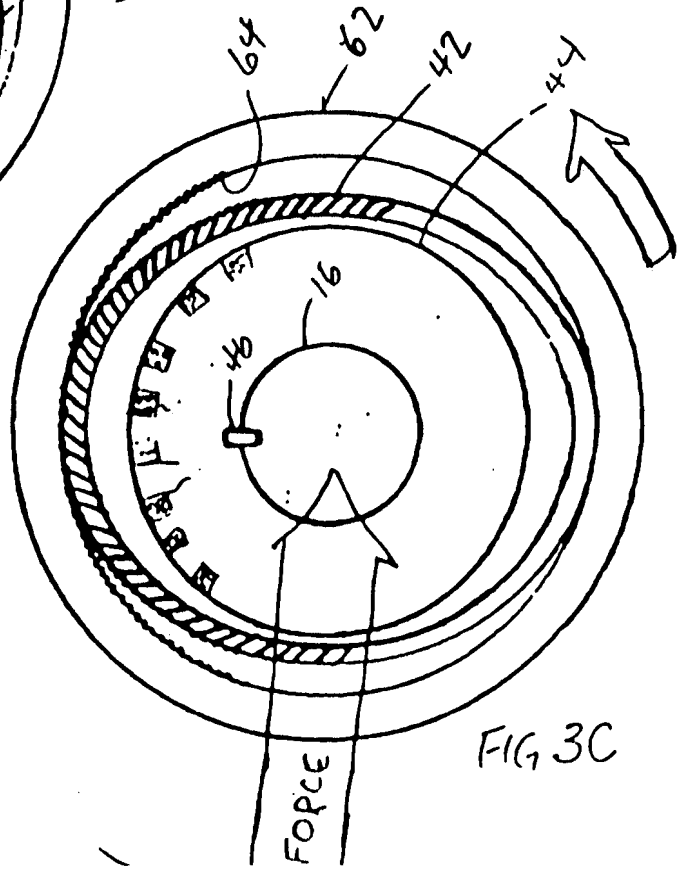

FIG 3C

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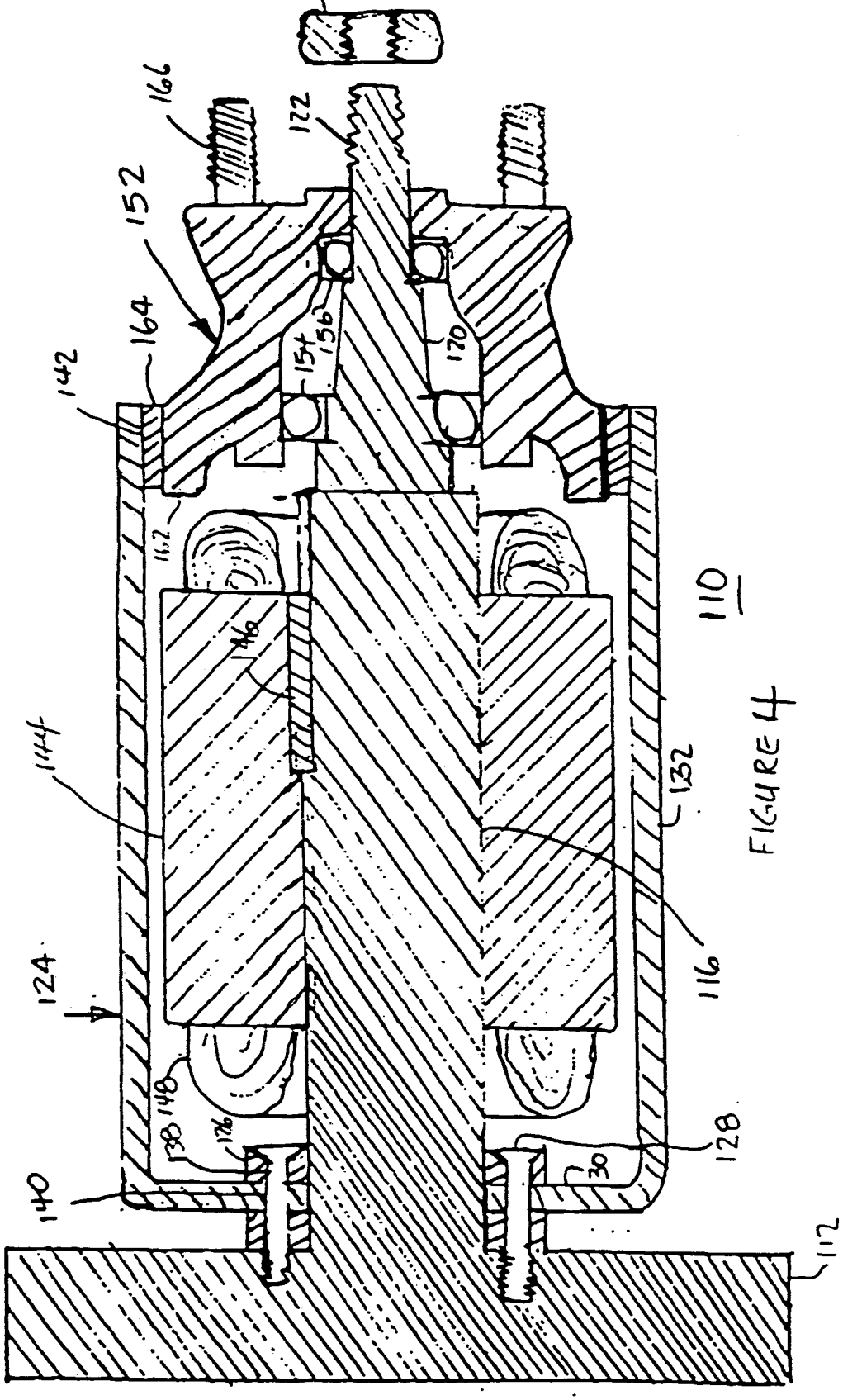
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FIGURE 4

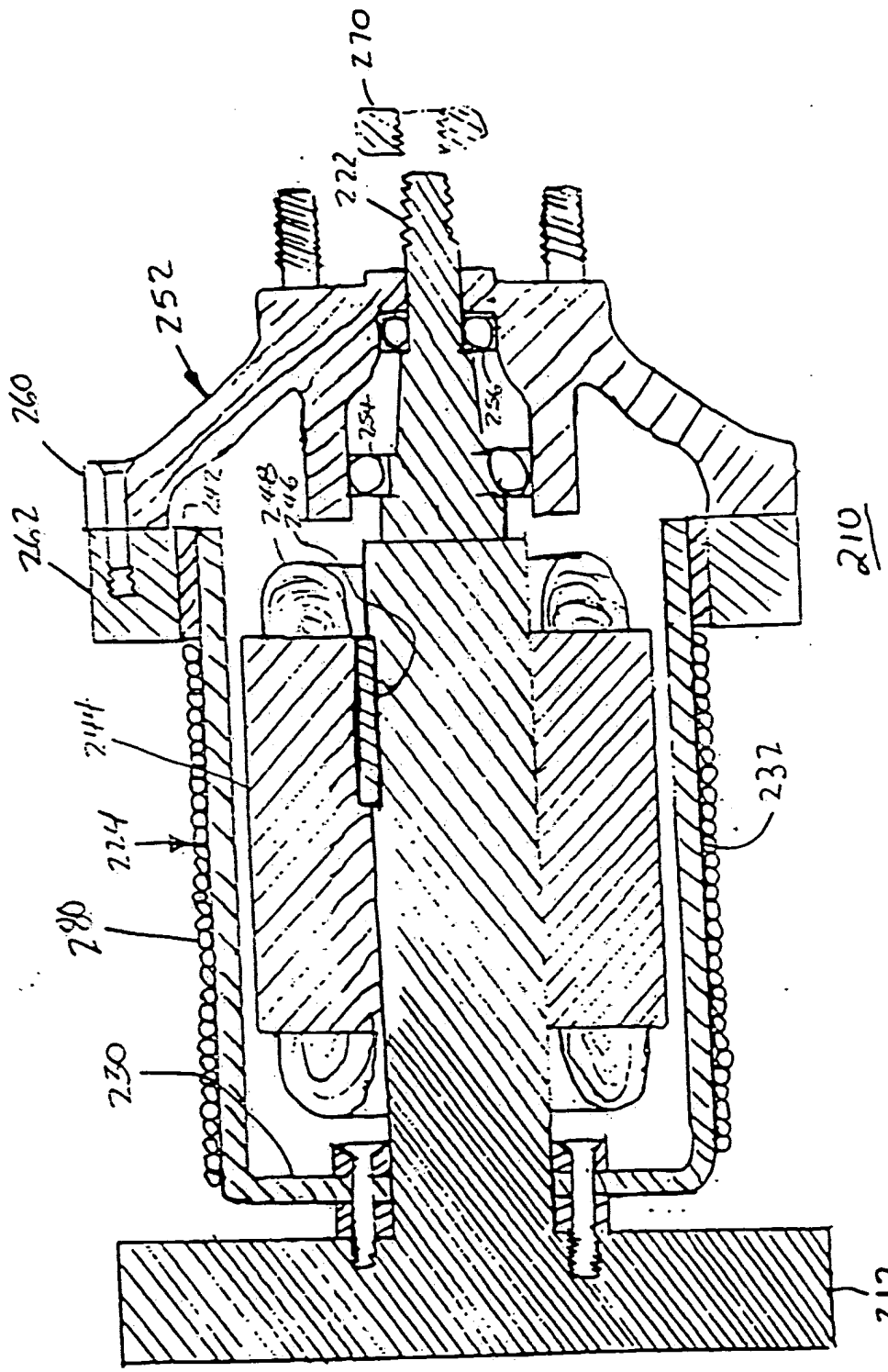
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FIGURE 5

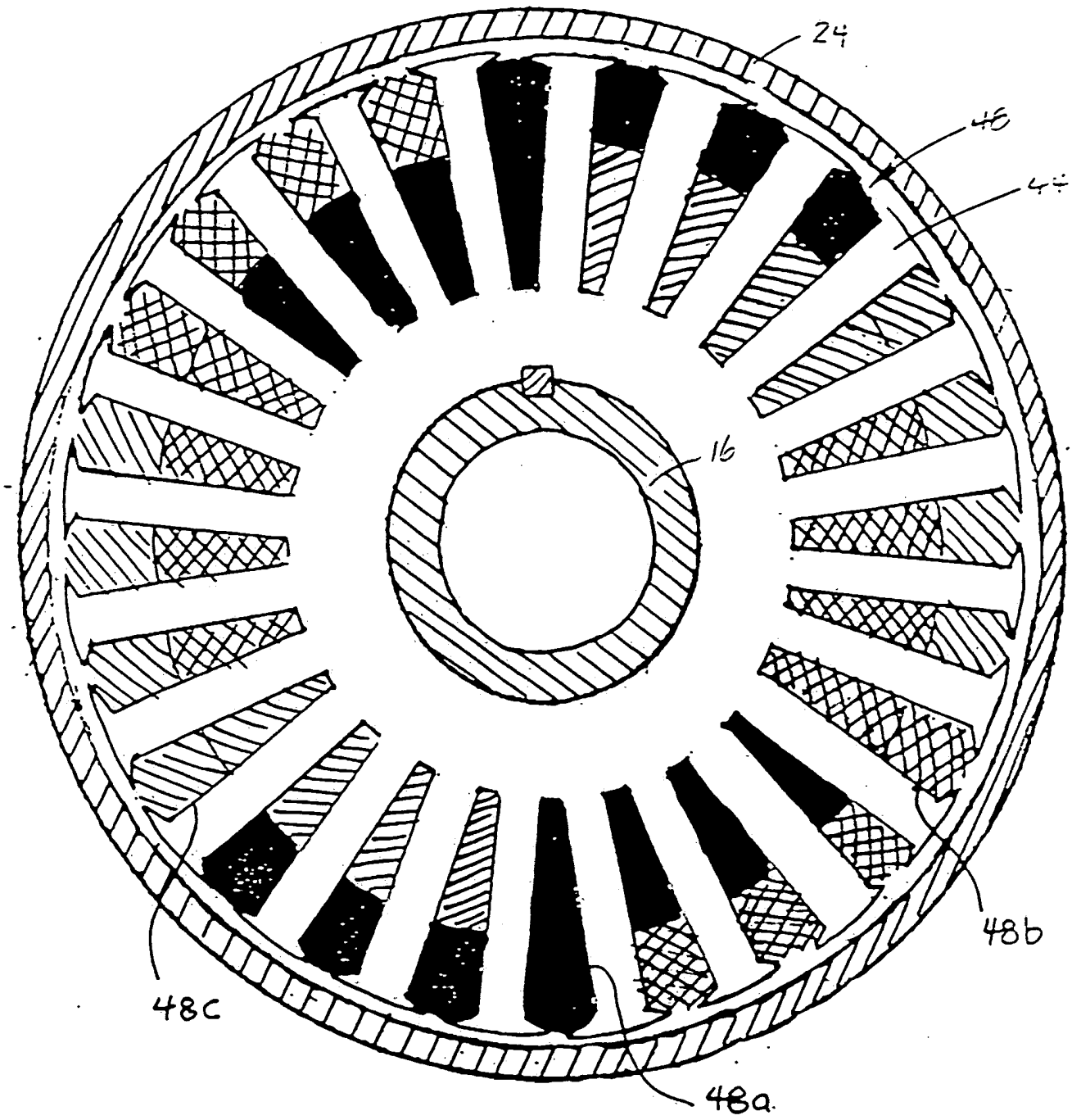

FIGURE 6

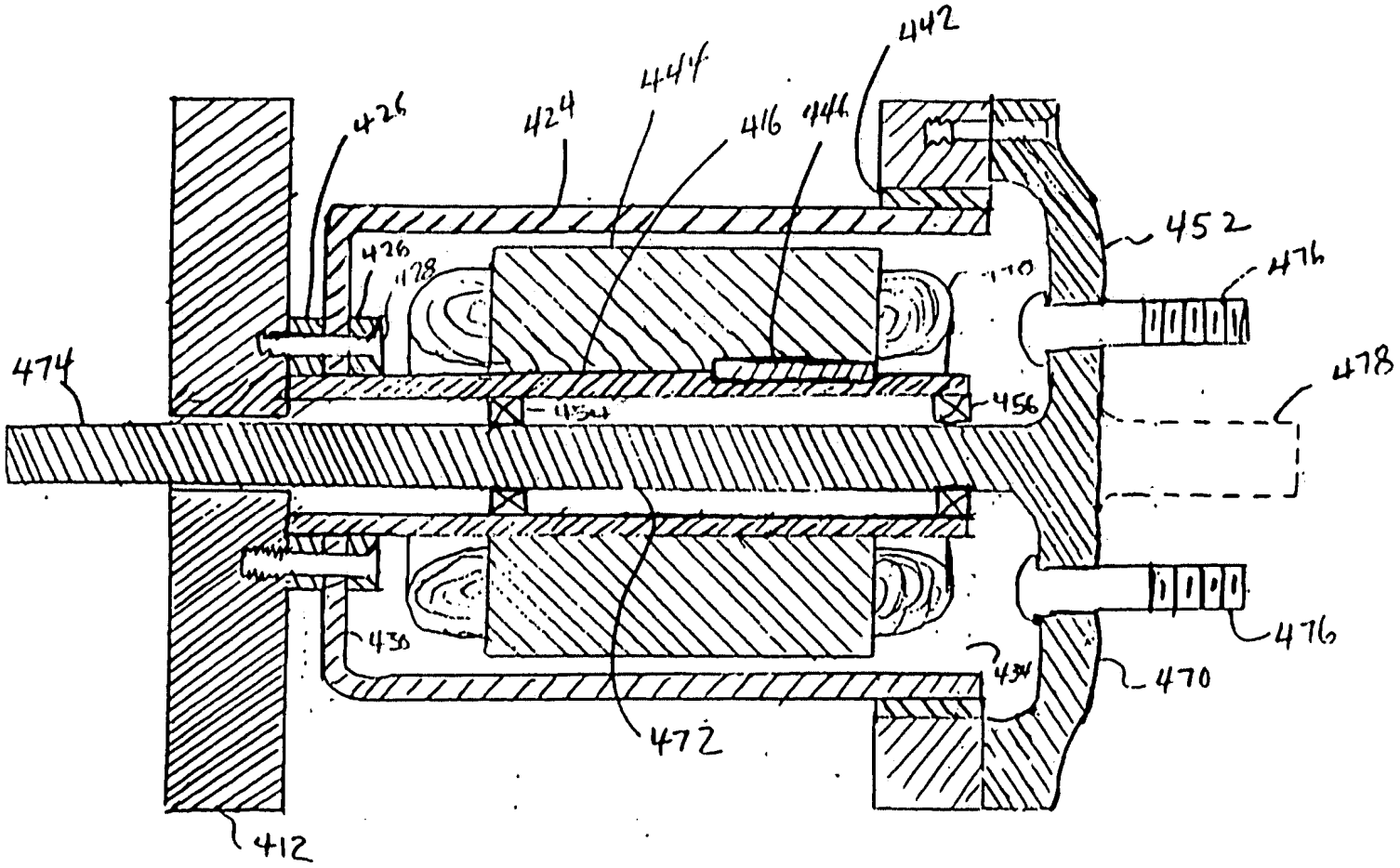

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FIG 7

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

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INVENTOR(S)		
Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
ERNEST	DAVISON	NASSAGEWAYA, ONTARIO CANADA

__ Additional inventors are being named on the ___ separately numbered sheets attached hereto

TITLE OF THE INVENTION (280 characters max)

PULL-PULL VARIABLE RELUCTANCE FLEXISPLINE MOTOR

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ENCLOSED APPLICATION PARTS *(check all that apply)*

V Specification *Number of Pages* 23 — [ ] Small Entity Statement

V Drawing(s) *Number of Sheets* 10 — V Other (specify) Abstract; 6 pages claims

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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__ Yes, the name of the U.S. Government agency and the Government contract number are: _____

Respectfully submitted,

SIGNATURE E.H. Oldham

Date 30/08/01

TYPED or PRINTED NAME E.H. Oldham

REGISTRATION NO. (if appropriate) 25,314

TELEPHONE 905 627 0509

Docket Number: EHO 01155

Aug 30/01

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APPLICATION # 60/316,295
4/Sept/01

ERNIE

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ERNEST	DAVISON	NASSAGEWAYA ONTARIO CANADA

☐ *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

FLEXISPLINE MOTOR CORE HAVING VARIABLE WIDTH TEETH AND WINDING THEREFORE

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 23 ☐ Small Entity Statement

☑ Drawing(s) *Number of Sheets* 9 ☑ Other (specify) Claims + Abstract

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FILING FEE AMOUNT ($): 75.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____

SEPT 17

Respectfully submitted,

SIGNATURE E H Oldham Sept 17 Date 12/09/01

TYPED or PRINTED NAME Edward H. Oldham REGISTRATION NO. *(if appropriate)* 25314

TELEPHONE 905 627 0509 Docket Number: EH001157

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APPLICATION # 60/322,471 17/SEPT/01

ABSTRACT

A core for a flexispline motor is enclosed within a distortable flexispline having the shape of an open tin can, such that under rest conditions the space between the flexispline and the core is constant. The core of the motor is shaped as in a hub and spoke configuration, with spokes having variable widths. Coils are fitted to the spokes and are connected in pairs such that pairs of coils on opposing "spokes" are in series bucking relationship. A second set of coils which overlap the first coils are connected in a non-bucking manner to increase the magnetic flux produced by the coils on opposing spokes. The flexispline has a flexible ring gear incorporated in its outer surface near the open end which when magnetically attracted ceases to have a circular shape and forms an elliptical shape. Under these conditions the points of major axis of the ellipse so formed contact a surrounding ring gear which is mounted on a rotating hub. The points of the flexible ring gear which correspond to the minor axis contact the surface of the core. As the magnetic force rotates the elliptical shape rotates, but the flexispline itself does not rotate. Because the number of teeth on the ring gear and the flexible gear are different, the hub is forced to rotate.

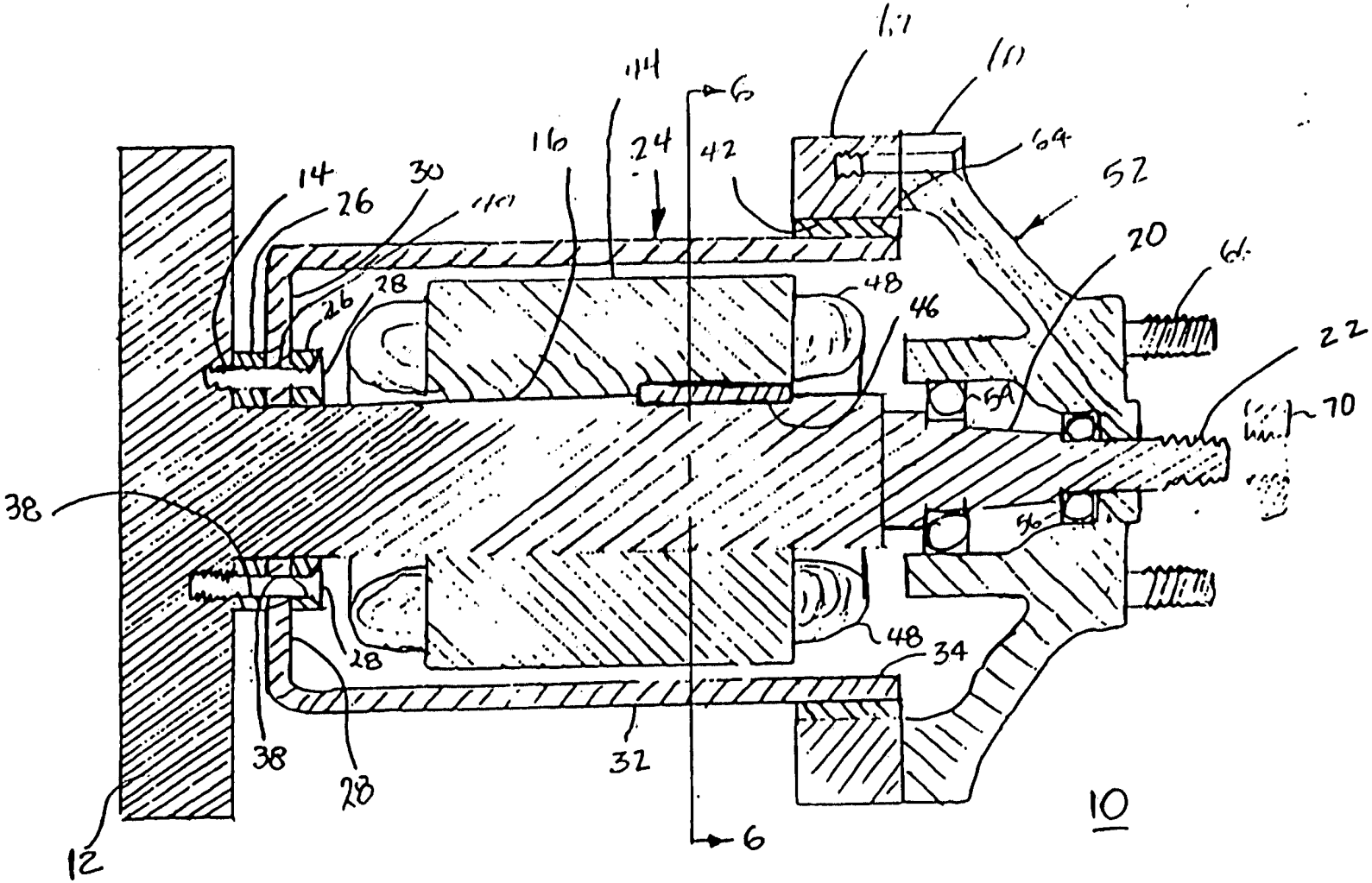
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FIGURE 1

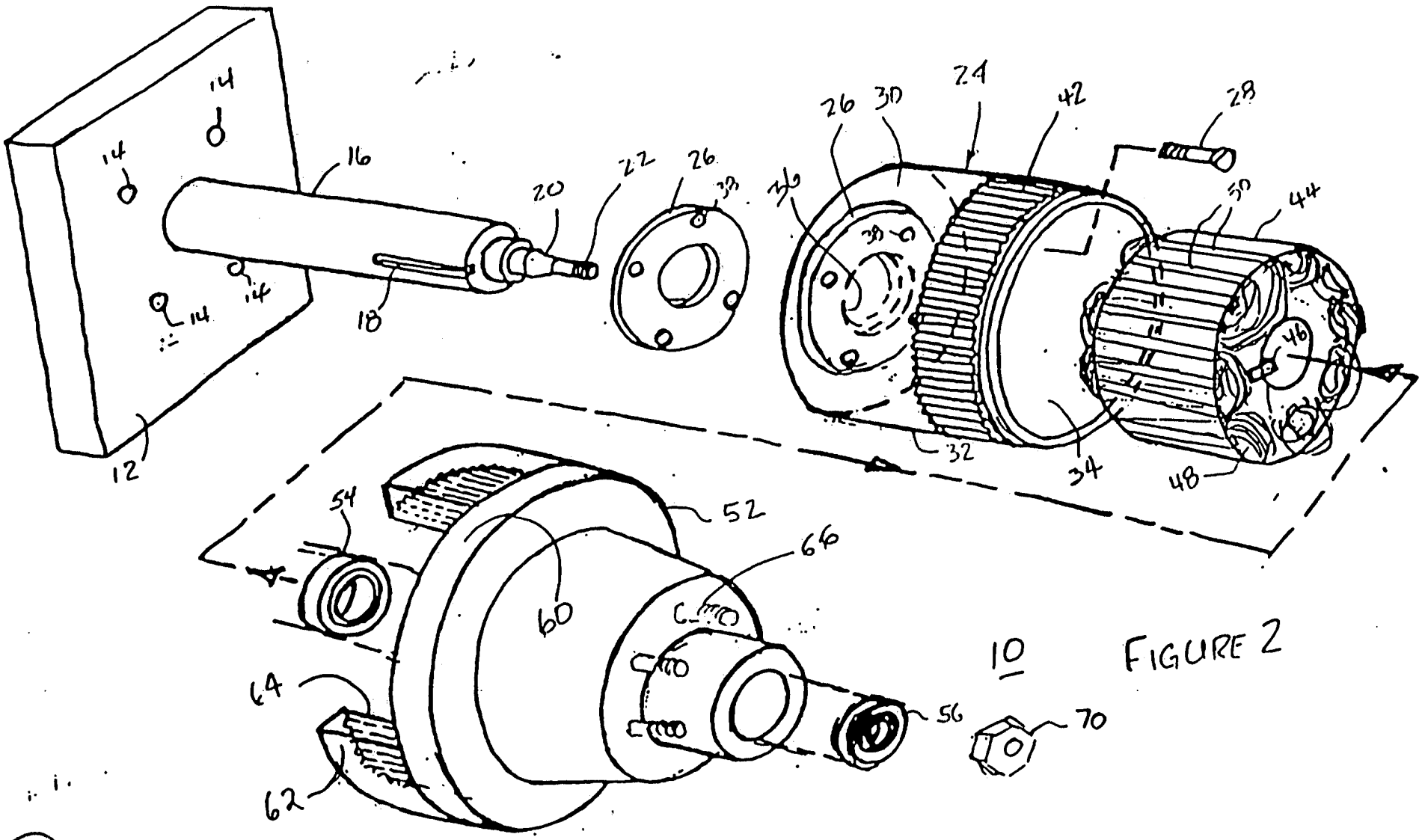
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FIGURE 2

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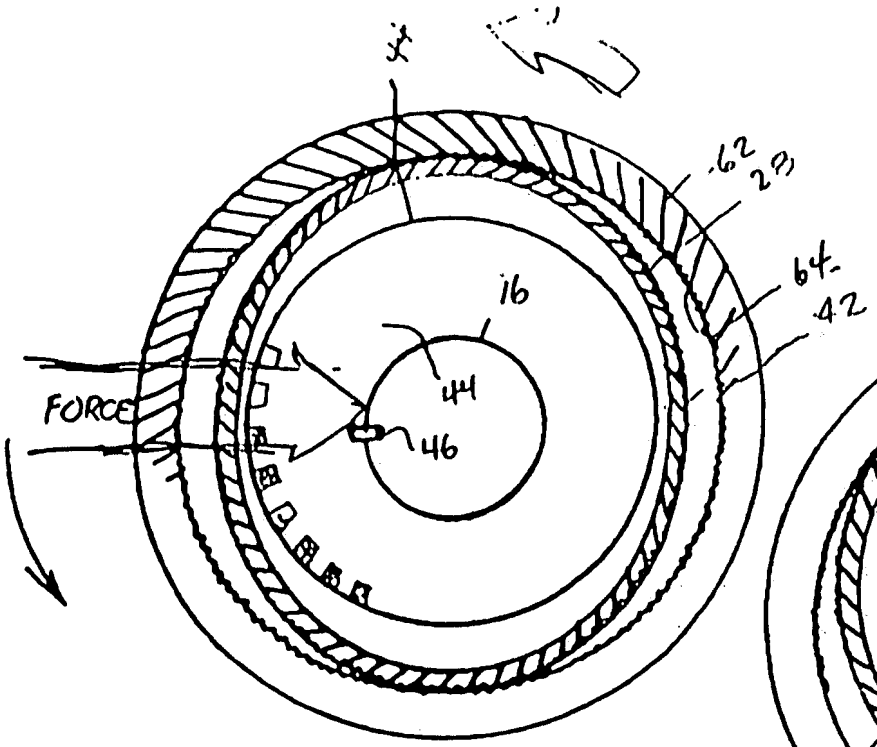

FIG 3A

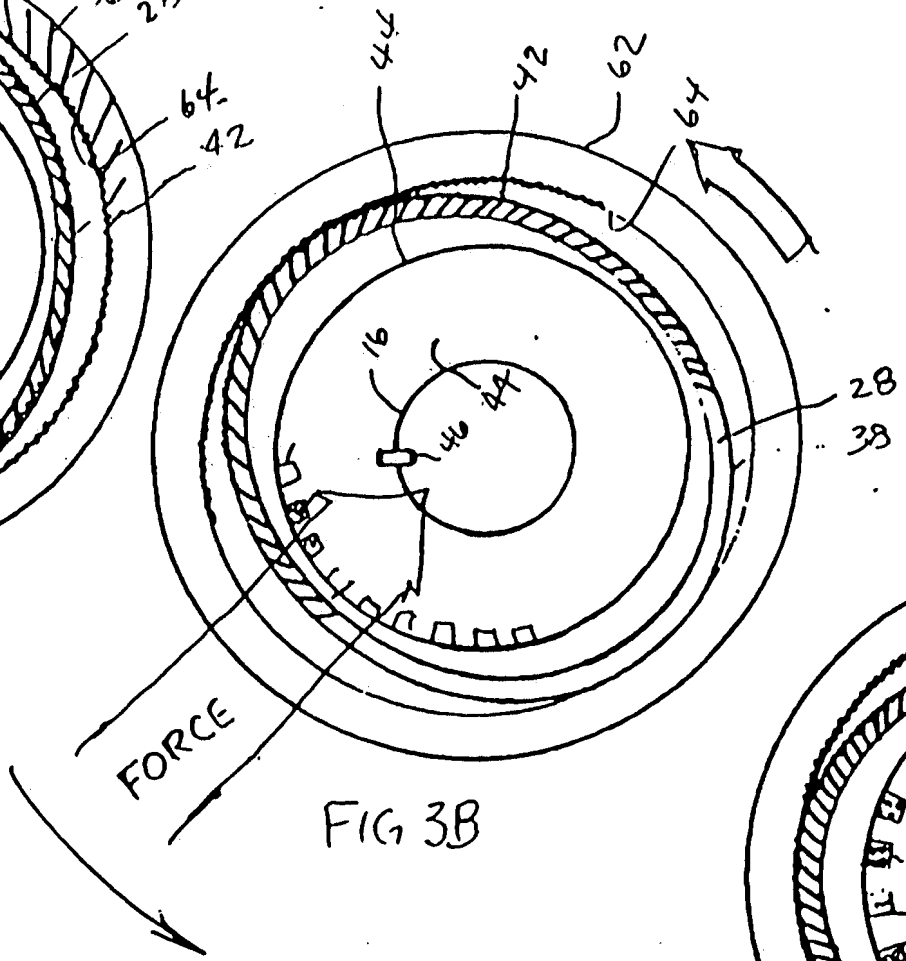

FIG 3B

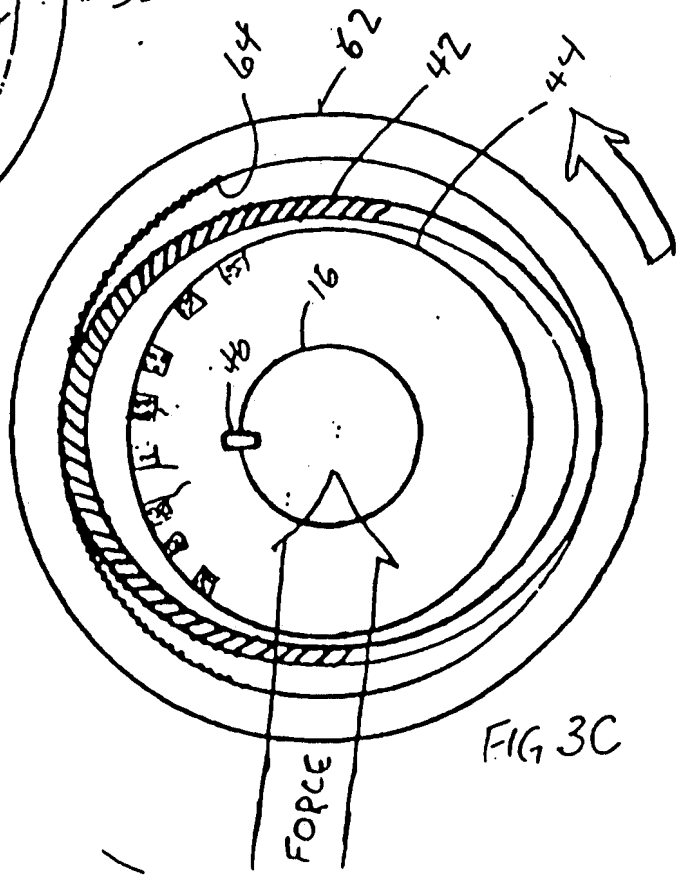

FIG 3C

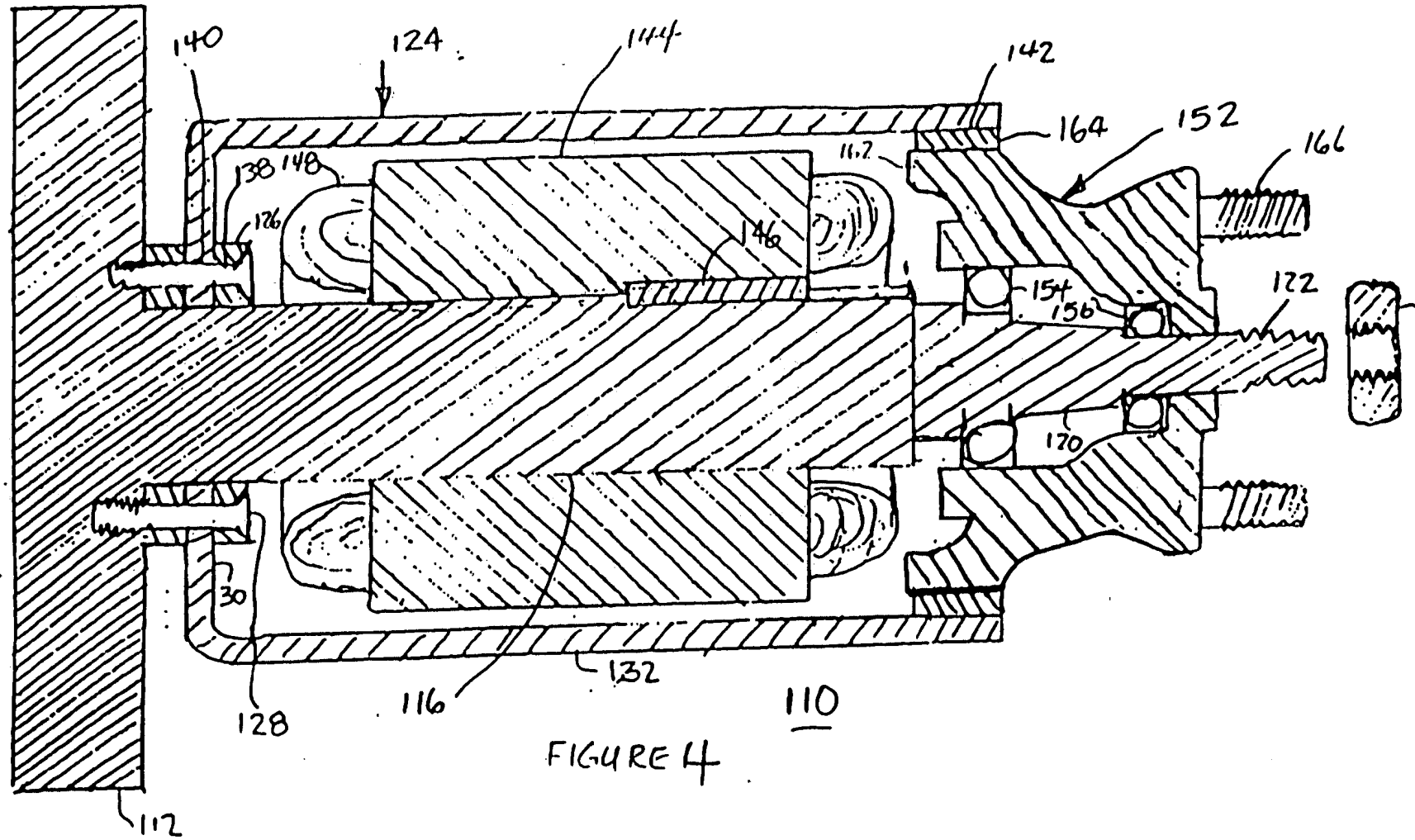
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FIGURE 4

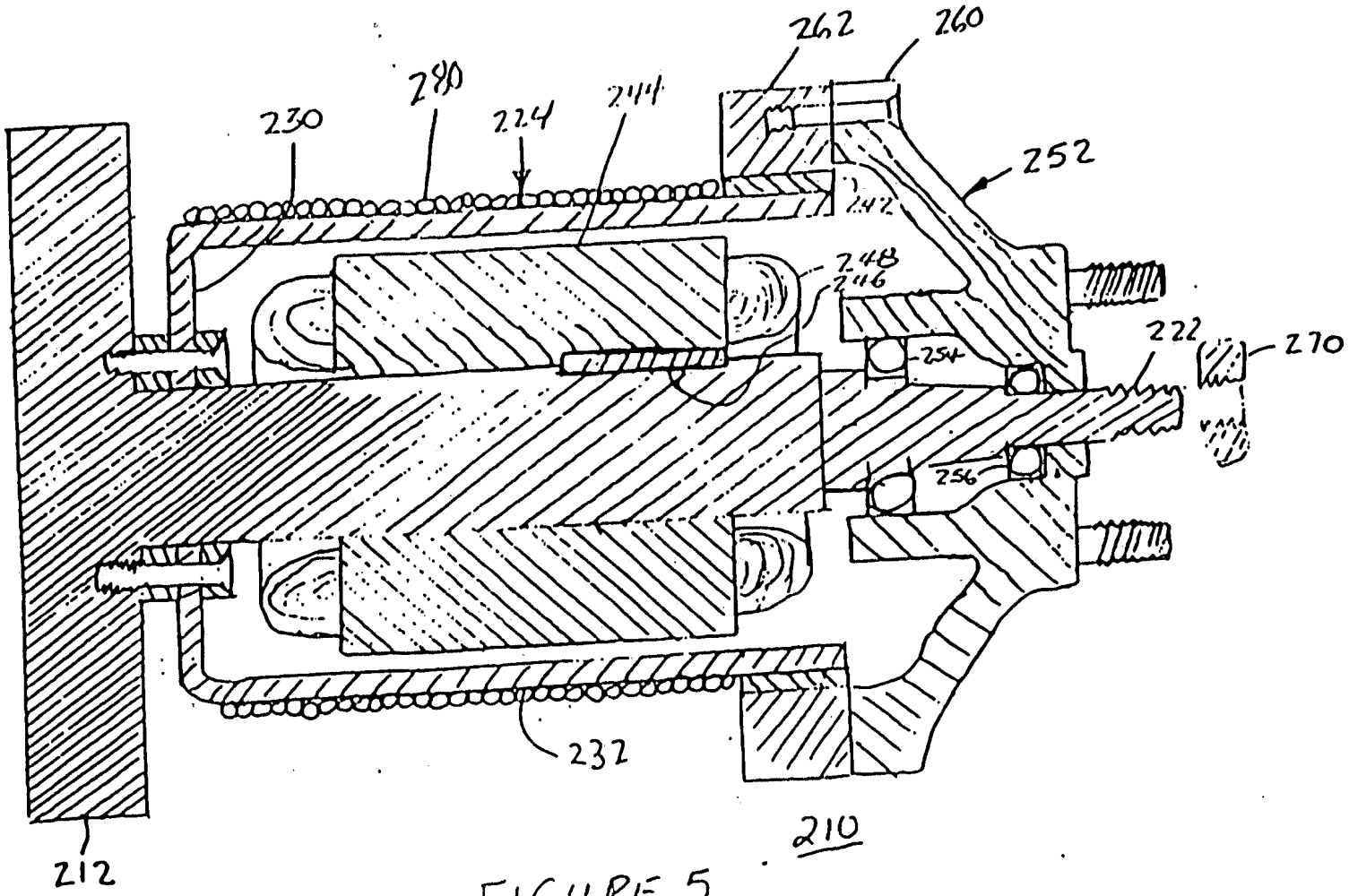
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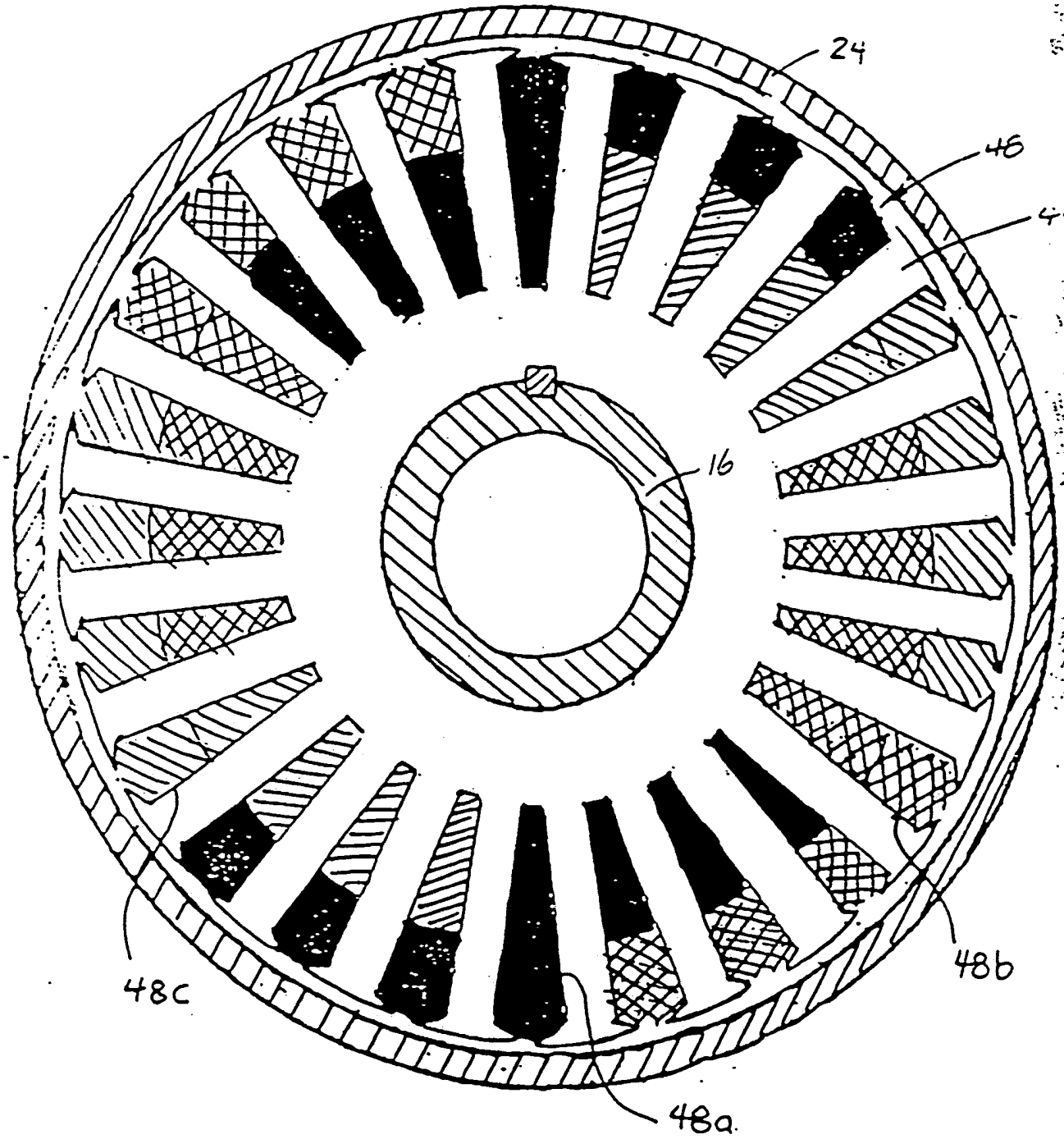
FIGURE 5



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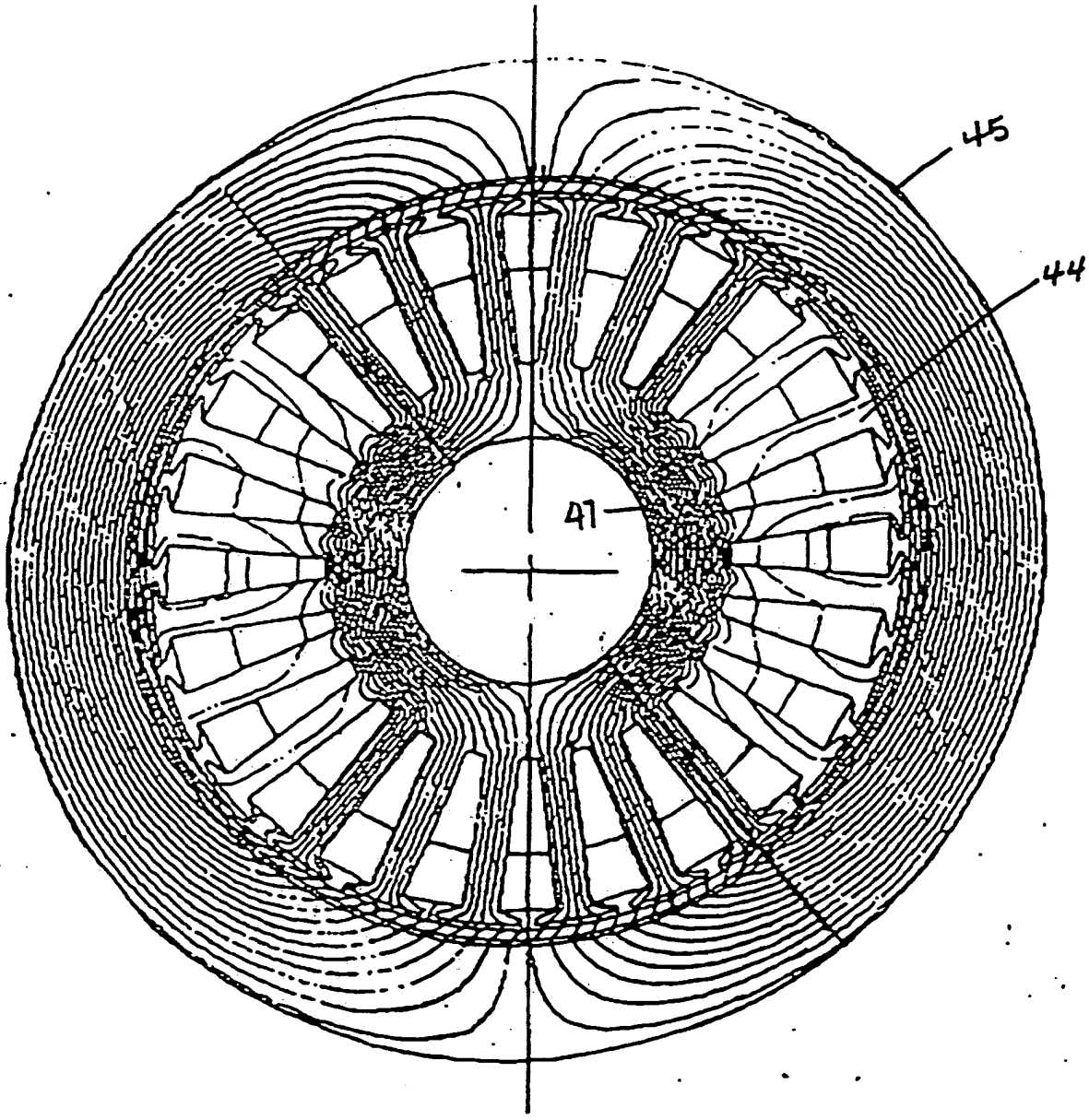

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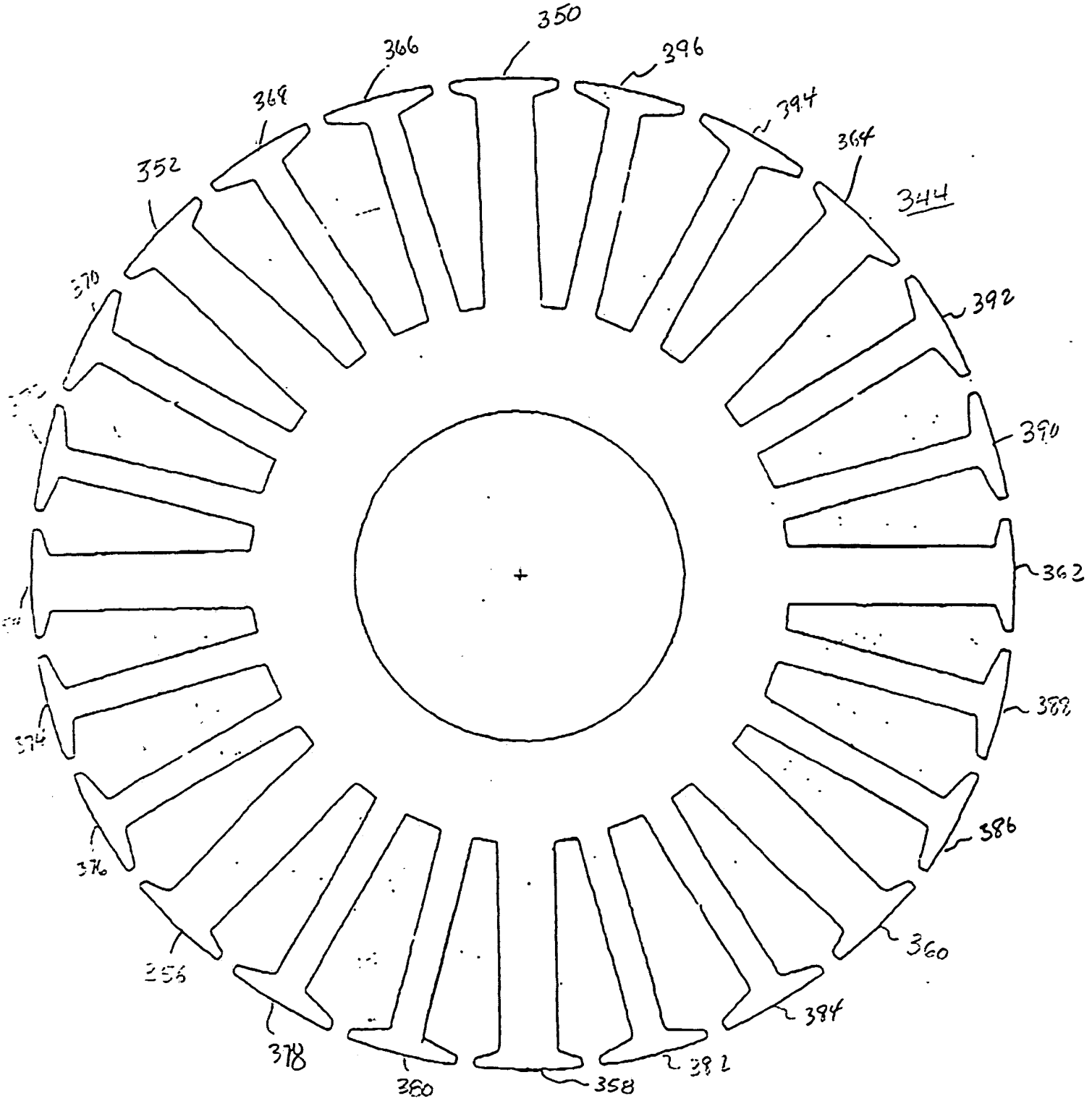
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FIGURE 8

Ernie

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INVENTOR(S)

Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
ERNEST	DAVISON	NASSAGEWAYA ONTARIO CANADA

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TITLE OF THE INVENTION (280 characters max)

SPLINED ANCHOR FOR FLEXISPLINE SLEEVE

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☐ Specification *Number of Pages* 12 ☐ Small Entity Statement

☐ Drawing(s) *Number of Sheets* 1 ☑ Other (specify) abstract

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Respectfully submitted,

SIGNATURE [signature] Date 11/01/02

TYPED or PRINTED NAME Edward H. Oldham REGISTRATION NO. (if appropriate) 25314

TELEPHONE 905 627 0509 Docket Number: EHO 01159

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APPLICATION # 60/347/253
JAN 14/02

Edward H. Oldham, P.Eng; BASc; MASc, FPTIC
Patent and Trade Mark Agent

20 Jameson Drive
Dundas, Ontario
L9H 5A2
Tel. (905) 627-0509
Fax (905) 628-3831
E mail: oldham@oldhamwhynot.com

#1 ORIGINAL

APPLICATION # 60/355,832

FEB 11 2002

FEB 13/02

INVENTOR(s): DAVISON, ERNEST

REF: EHO 01158

TITLE: "PULL-PULL TRICOIDAL FLEXISPLINE MOTOR"

Commissioner of Patents & Trademarks
Washington, D.C., 20231, U.S.A.

Sir:

I am enclosing herewith the following papers in connection with the provisional application for patent identified above.

- Specification, Claims and Abstract of the Disclosure
- ~~Declaration, and Power of Attorney~~
- Copy each of: 14 sheets of the drawing(s)
- ~~Assignment~~

Enclosed is a draft in the amount of $ 80.00. If there are any other charges needed, please deduct from Deposit Account No. 15-0445.

Respectfully,

E H Oldham

Edward H. Oldham

Encl.

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EARNEST	DAVISON	NASSAGEWAYA

☐ *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

FLEXISPLINE MOTOR

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☐ Specification *Number of Pages* 24 ☐ Small Entity Statement

☐ Drawing(s) *Number of Sheets* 6 ☑ Other (specify) ABSTRACT

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Respectfully submitted,

SIGNATURE EH Oldham

Date 07.09.01

TYPED or PRINTED NAME Edward H. Oldham

REGISTRATION NO. *(if appropriate)* 25314

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This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

INVENTOR(S)		
Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)
ERNEST	DAVISON	NASSAGEWAYA ONTARIO CANADA

☐ *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

SWITCHED RELUCTANCE FLEXISPLINE MOTOR

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Respectfully submitted,

SIGNATURE E H Oldham

TYPED or PRINTED NAME E. Oldham

TELEPHONE 905 627 0509

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APPLICATION # 60/316/293
4 SEPT/01

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